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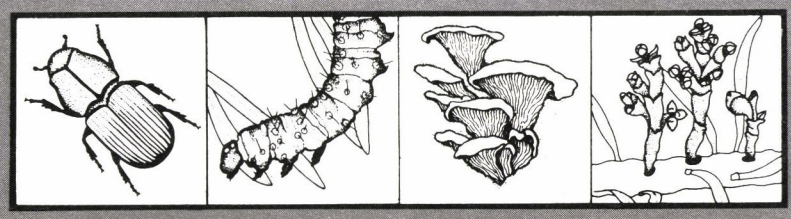

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# CONTAINERIZED ENGELMANN SPRUCE SEEDLING DISEASES AT THE USDA FOREST SERVICE NURSERY COEUR D'ALENE, IDAHO

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by

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## ABSTRACT

An evaluation was conducted at the USDA Forest Service Nursery, Coeur d'Alene, Idaho, to quantify the occurrence of diseases in the spring 1984 crop of containerized Engelmann spruce seedlings. The crop included 19 separate seedlots from seven National Forests in the Northern Region. An overall production rate of 94.5 percent was achieved for the crop (5.5 percent of the crop was lost to diseases or other mortality factors). Dead or diseased seedlings accounted for only 0.7 percent of the total losses, whereas empty cells accounted for the remaining 4.8 percent. Major disease organisms included *Sirococcus strobilinus*, *Fusarium oxysporum*, *F. avenaceum*, *F. solani*, *F. tricinctum*, *Cylindrocarpon tenue*, *Phoma herbarum*, *P. fimeti*, and *Botrytis cinerea*. *Sirococcus* caused disease in 18 of the 19 seedlots and was usually encountered about 11 weeks after sowing. *Fusarium* diseases occurred with greatest frequency shortly after germinate emergence.

## INTRODUCTION

Engelmann spruce (*Picea engelmanni* Parry) is an important species for reforestation of many high elevation forest sites in the northern Rocky Mountains. Several hundred thousand spruce seedlings are grown annually in containers at the USDA Forest Service Nursery, Coeur d' Alene, Idaho, to meet reforestation demands.

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Although diseases of containerized spruce account for some crop losses, extensive disease losses are very infrequent. In the past, major diseases of containerized spruce recognized at the nursery included damping-off/root disease caused primarily by Fusarium spp. and Botrytis blight. However, in 1983 another disease caused by Sirococcus strobilinus Preuss was found for the first time on spruce at Coeur d'Alene (James 1983c). Although this disease had previously been reported at several nurseries in British Columbia (Sutherland et al. 1981), its occurrence on containerized spruce in the United States had not been reported.

An evaluation was conducted at the Coeur d'Alene Nursery to quantify occurrence of Sirococcus tip blight and other diseases on containerized Engelmann spruce. The evaluation was aimed at identifying causes and determining extent of diseases throughout the seedling production cycle. Disease relationships among the different seedlots were also determined.

## MATERIALS AND METHODS

The 1984 spring crop of containerized Engelmann spruce seedlings at the nursery was grown from 19 seedlots from seven National Forests in the Northern Region (table 1). Fourteen of these seedlots were selected for analyses of seed germination and germinate emergence. Two trays of seedligns (400 Ray Leach Pine Cells®) were randomly sampled from each seedlot. Number of emerged germinates per cell was tallied approximately 3 weeks after sowing, and diseased (damped-off) germinates removed for isolation of associated organisms. For all isolations, germinates were washed thoroughly under running tap water to remove soil particles and placed on a selective medium for Fusarium (Komada 1975). After counting, sample trays were thinned to one germinate per cell. Total emerged germinates and percent of germinates removed during thinning were calculated.

The number of seeds sown per cell was based on germination tests conducted by the nursery. The biomachine seeder was set up to place from 2 to 6 seeds per cell, depending on seedlot. Percent of the estimated number of seeds sown that germinated and produced a germinate was calculated about 3 weeks after sowing.

Number of empty cells (without seedlings) was estimated for each of the 19 seedlots about 6 weeks after sowing. Four trays (800 cells) were randomly selected; empty cells were tallied and percent of cells with seedlings extrapolated for the entire seedlot.

All seedlots were examined three more times at about 3- to 5-week intervals (6, 11, and 14 weeks after sowing) for seedlings with disease symptoms. Number of symptomatic (chlorotic-necrotic) seedlings was tallied and each removed for isolation of associated organisms. Although several fungi commonly grew from diseased seedlings, only those suspected of being pathogens were identified. Tests to confirm pathogenicity of these organisms were not conducted.

After seedlings were removed from greenhouses and placed outside under shade (about 20 weeks after sowing), nursery crews tallied number of empty cells and dead seedlings while consolidating cells. Isolations were not made from most of these older dead seedlings.

Table 1.--Engelmann spruce seedlots from which containerized seedlings were grown during the 1984 spring crop at the USDA Forest Service Nursery, Coeur d'Alene, Idaho.

| Seedlot | Ranger District | Collection Location National Forest | Elevation (ft) | Greenhouse number | No. seeds sown/cell[1] |
|---|---|---|---|---|---|
| 0281 | Wallace | Idaho Panhandle | 4,000 | 9 | 3 |
| 0353 | Fisher River | Kootenai | 5,000 | 9 | 2 |
| 0728 | Ninemile | Lolo | 6,000 | 8 | 4 |
| 0747 | Elk City | Nezperce | 5,000 | 9 | 6 |
| 0759 | Elk City | Nezperce | 5,000 | 9 | 2 |
| 1355 | Fortine | Kootenai | 5,000 | 9 | 3 |
| 1670 | Bonner's Fy. | Idaho Panhandle | 5,000 | 9 | 6 |
| 4012 | Powell | Clearwater | 5,600 | 8 | 6 |
| 4093 | Stevensville | Bitterroot | 6,000 | 8 | 2 |
| 4199 | Rexford | Kootenai | 5,000 | 8 | 2 |
| 4215 | Red Ives | Idaho Panhandle | 4,400 | 9 | 2 |
| 4374 | Powell | Clearwater | 5,300 | 8 | 2 |
| 4793 | Missoula | Lolo | 5,900 | 8 | 2 |
| 4935 | Bonner's Fy. | Idaho Panhandle | 5,000 | 8 | 2 |
| 4938 | Bonner's Fy. | Idaho Panhandle | 5,600 | 8 | 2 |
| 6053 | Fernan | Idaho Panhandle | 3,800 | 9 | 2 |
| 6081 | Hebgen Lake | Gallatin | 7,200 | 8 | 2 |
| 6082 | Gardiner | Gallatin | 6,800 | 8 | 2 |
| 6086 | Hebgen Lake | Gallatin | 6,800 | 8 | 2 |

[1]Target number of seeds to be placed in each cell by the Vancouver Biomachine based on presowing germination tests.

## RESULTS

Emergence of spruce germinates among the different seedlots is summarized in table 2. Extensive variation existed among the sampled seedlots. Differences between estimated number of seed sown and number of emerged germinates were due to non-uniformity in sowing (more or less seed sown per cell than was desired) and other than expected germination rates. In seedlot 0281, for example, an estimated 1,200 seeds were sown (three per cell). Although 854 germinates emerged (71.2 percent), only 400 were needed (one per cell). Therefore, about 56 percent of the emerged germinates had to be removed during thinning. In this seedlot, only 6.3 percent of the cells were empty (without germinates).

Production and loss figures for the 1984 spring-summer crop of containerized Engelmann spruce seedlings at the nursery are summarized in table 3. An overall production rate (percent of cells sown that produced satisfactory seedlings) of 94.5 percent was achieved for the entire crop. This would indicate that only 5.5 percent of the crop was lost to diseases or other mortality factors during production. Among the different seedlots, production rates varied from a low of about 81 percent (seedlot 1670) to a high of 99 percent (seedlot 6082). Estimated number of seedlings to be produced (table 3, column 5) closely approximated actual number produced. This indicated that sampling a small portion of the crop about 6 weeks after sowing gave a reliable estimate of final seedling production.

The nursery routinely conducts a 1 percent sample of the crop at the time of thinning to estimate final production. Their sample for the 1984 spring-summer crop indicated an expected total production of 320,600 which was close to our estimates and somewhat less than final production.

Losses outlined in table 3 are summarized by time of occurrence within the production cycle and major associated fungi. Losses from dead or diseased seedlings accounted for only 0.7 percent of the crop, whereas empty cells accounted for losses of 4.8 percent. Although disease occurred throughout the production cycle with peaks occurring between 3 and 11 weeks, an estimate made at 6 weeks of the amount of disease (0.5 percent) closely approximated actual disease losses.

The most damaging disease was caused by *Sirococcus strobilinus* (table 3). Other common disease organisms included at least two strains of *Fusarium oxysporum* Schlect., *F. roseum* (Lk.) em. Snyd. & Hans., *Cylindrocarpon destructans* (Zinnsm.) Scholten (= *C. radidicola* Woll.), *Phoma herbarum* Westd., *P. fimeti* Brun., and *Botrytis cinerea* Pers. ex Fr. Detailed descriptions of these organisms are included in the Appendix.

Occurrence of the three fungi most commonly isolated at various intervals during the production cycle is outlined in table 4. Although *S. strobilinus* was isolated throughout the sample period, disease caused by this fungus was most commonly encountered 11 weeks after sowing. On the other hand, disease caused by *F. oxysporum* was most common earlier (3 weeks) and decreased as the seedlings grew older. Seedling mortality associated with *C. destructans* occurred with about equal frequency during the first 11 weeks and then decreased significantly.

Table 2.—Emergence of containerized Engelmann spruce germinants within selected seedlots at the USDA Forest Service Nursery, Coeur d'Alene, Idaho.[1]

| Seedlot[2] | Percent of Cells[3] | | | | | | | | Total emerged germinants | Percent thinned[4] | Est. seed sown[5] | Percent emerged[6] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | | | | |
| 0281 | 6.3 | 21.5 | 37.3 | 25.0 | 7.8 | 2.0 | 0.2 | 0 | 854 | 56.1 | 1,200 | 71.2 |
| 0353 | 20.0 | 48.3 | 25.5 | 4.5 | 1.5 | 0.2 | 0 | 0 | 480 | 33.3 | 800 | 60.0 |
| 0728 | 14.7 | 31.3 | 32.0 | 15.3 | 5.0 | 1.7 | 0 | 0 | 679 | 49.8 | 1,600 | 42.4 |
| 0747 | 0 | 4.3 | 9.7 | 25.5 | 23.0 | 20.3 | 10.8 | 6.4 | 1,624 | 75.4 | 2,400 | 67.7 |
| 0759 | 8.2 | 29.0 | 50.0 | 9.5 | 2.5 | 0.8 | 0 | 0 | 685 | 46.4 | 800 | 85.6 |
| 1355 | 13.5 | 40.7 | 28.0 | 13.3 | 4.0 | 0.5 | 0 | 0 | 620 | 44.2 | 1,200 | 51.7 |
| 1670 | 19.5 | 30.8 | 29.8 | 12.2 | 6.5 | 1.0 | 0.2 | 0 | 638 | 49.5 | 2,400 | 26.6 |
| 4012 | 1.5 | 12.5 | 24.8 | 26.5 | 21.3 | 9.7 | 2.7 | 1.0 | 1,195 | 67.0 | 2,400 | 49.8 |
| 4093 | 1.0 | 16.0 | 62.5 | 14.5 | 5.5 | 0.3 | 0.2 | 0 | 837 | 52.7 | 800 | 104.6 |
| 4215 | 2.8 | 23.0 | 60.2 | 12.5 | 1.5 | 0 | 0 | 0 | 748 | 48.0 | 800 | 93.5 |
| 4793 | 0.5 | 11.0 | 61.5 | 20.5 | 4.8 | 1.7 | 0 | 0 | 883 | 54.9 | 800 | 110.4 |
| 6053 | 0.2 | 11.0 | 62.5 | 22.3 | 3.0 | 1.0 | 0 | 0 | 880 | 54.7 | 800 | 110.0 |
| 6081 | 0.2 | 9.5 | 71.5 | 16.8 | 1.0 | 0.8 | 0.2 | 0 | 848 | 52.9 | 800 | 106.0 |
| 6082 | 0.2 | 9.5 | 68.5 | 17.0 | 3.3 | 1.5 | 0 | 0 | 872 | 54.2 | 800 | 109.0 |

[1] 400 cells (two trays) sampled per seedlot - see table 1 for desired number of seeds sown per cell.
[2] See table 1 for seedlot descriptions.
[3] Percent of sampled cells with 0 - >6 emerged germinants per cell.
[4] Percent of the emerged germinants that were thinned and removed from cells.
[5] Based on the number of seeds per cell programmed into the sowing machine.
[6] Percent of the estimated sown seed which produced an emerged germinant.

Table 3—Containerized Engelmann spruce seedling production and losses at the USDA Forest Service Nursery, Coeur d'Alene, Idaho - spring 1984.

| Seedlot number | No. trays | No. cells | Est. cell fill %[1] | Estimated number of seedlings[2] | No. diseased seedlings tallied[3] 3 wks | 6 wks | 11 wks | 14 wks | Total | Est. % Dis.[4] | No. seedlings killed by pathogens[5] Siro | Fus oxy | Cyl | Fus | Phoma | Bot | Other or none[6] | No. empty cells[7] | % | Number of dead seedlings[8] | % | Final no. of seedlings[9] | Production rate[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0281 | 58 | 11,600 | 94.3 | 10,933 | 13 | 3 | 10 | 6 | 32 | 0.3 | 1 | 15 | 5 | 0 | 0 | 2 | 9 | 50 | 6.0 | 697 | 0.4 | 10,853 | 93.6 |
| 0353 | 286 | 57,200 | 80.0 | 45,760 | 51 | 16 | 34 | 7 | 108 | 0.2 | 9 | 63 | 7 | 5 | 5 | 0 | 19 | 5,627 | 9.8 | 197 | 0.3 | 51,376 | 89.8 |
| 0728 | 46 | 9,200 | 84.5 | 7,774 | 11 | 10 | 9 | 4 | 34 | 0.4 | 6 | 17 | 10 | 0 | 0 | 0 | 1 | 986 | 10.7 | 41 | 0.5 | 8,173 | 88.8 |
| 0747 | 216 | 43,200 | 100.0 | 43,200 | 83 | 72 | 94 | 33 | 282 | 0.7 | 60 | 170 | 45 | 1 | 5 | 1 | 0 | 391 | 0.9 | 388 | 0.9 | 42,421 | 98.2 |
| 0759 | 216 | 43,200 | 91.8 | 39,636 | 42 | 45 | 140 | 15 | 242 | 0.5 | 129 | 82 | 16 | 0 | 4 | 1 | 10 | 2,474 | 5.7 | 298 | 0.7 | 40,428 | 93.6 |
| 1355 | 64 | 12,800 | 85.5 | 10,944 | 25 | 13 | 41 | 5 | 84 | 0.8 | 22 | 13 | 35 | 0 | 0 | 0 | 14 | 1,609 | 12.6 | 113 | 0.9 | 11,078 | 86.5 |
| 1670 | 46 | 9,200 | 78.8 | 7,245 | 27 | 18 | 28 | 9 | 82 | 1.1 | 7 | 34 | 30 | 0 | 1 | 0 | 10 | 1,624 | 17.7 | 95 | 1.1 | 7,481 | 81.3 |
| 4012 | 173 | 34,600 | 97.5 | 33,735 | 31 | 31 | 65 | 7 | 134 | 0.4 | 47 | 22 | 23 | 0 | 7 | 1 | 34 | 273 | 0.8 | 189 | 0.5 | 34,138 | 98.7 |
| 4093 | 5 | 1,000 | 99.3 | 993 | 1 | 0 | 2 | 0 | 3 | 0.3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 8 | 0.8 | 3 | 0.3 | 989 | 98.9 |
| 4199 | 30 | 6,000 | 95.0 | 5,700 | 12 | 10 | 12 | 4 | 38 | 0.7 | 5 | 22 | 4 | 0 | 0 | 0 | 7 | 276 | 4.6 | 42 | 0.7 | 5,682 | 94.7 |
| 4215 | 14 | 2,800 | 97.3 | 2,723 | 4 | 1 | 2 | 0 | 7 | 0.3 | 0 | 2 | 1 | 0 | 0 | 0 | 4 | 64 | 2.3 | 10 | 0.4 | 2,726 | 97.4 |
| 4374 | 47 | 9,400 | 92.3 | 8,672 | 5 | 5 | 11 | 0 | 21 | 0.2 | 2 | 4 | 4 | 0 | 1 | 0 | 10 | 643 | 6.8 | 27 | 0.3 | 8,730 | 92.9 |
| 4793 | 58 | 11,600 | 99.5 | 11,542 | 9 | 6 | 20 | 5 | 40 | 0.3 | 17 | 10 | 3 | 0 | 0 | 0 | 10 | 120 | 1.0 | 64 | 0.6 | 11,416 | 98.4 |
| 4935 | 334 | 66,800 | 99.3 | 66,299 | 49 | 46 | 303 | 24 | 422 | 0.6 | 295 | 53 | 6 | 0 | 2 | 10 | 56 | 1,492 | 2.2 | 518 | 0.8 | 64,790 | 97.0 |
| 4938 | 41 | 8,200 | 99.3 | 8,139 | 22 | 18 | 27 | 2 | 69 | 0.8 | 30 | 15 | 1 | 0 | 0 | 0 | 23 | 90 | 1.1 | 95 | 1.2 | 8,015 | 97.7 |
| 6053 | 35 | 7,000 | 99.5 | 6,965 | 19 | 8 | 22 | 5 | 54 | 0.8 | 21 | 16 | 5 | 0 | 3 | 0 | 9 | 268 | 3.8 | 76 | 1.1 | 6,656 | 95.1 |
| 6081 | 41 | 8,200 | 99.0 | 8,118 | 9 | 7 | 31 | 4 | 51 | 0.6 | 30 | 11 | 0 | 0 | 0 | 0 | 10 | 63 | 0.8 | 65 | 0.8 | 8,072 | 98.4 |
| 6082 | 23 | 4,600 | 99.5 | 4,577 | 3 | 1 | 10 | 1 | 15 | 0.3 | 8 | 2 | 1 | 0 | 0 | 0 | 4 | 18 | 0.4 | 26 | 0.6 | 4,556 | 99.0 |
| 6086 | 35 | 7,000 | 96.0 | 6,720 | 2 | 2 | 4 | 1 | 9 | 0.1 | 1 | 2 | 0 | 1 | 0 | 0 | 5 | 252 | 3.6 | 40 | 0.6 | 6,708 | 95.8 |
| Totals | 1,768 | 353,600 | - | 329,675 | 418 | 312 | 865 | 132 | 1,727 | 0.5 | 691 | 555 | 196 | 7 | 28 | 15 | 235 | 16,975 | 4.8 | 2,337 | 0.7 | 344,288 | 94.5 |

[1] Based on sample of four trays (800 cells).
[2] Number expected from sample.
[3] Data obtained 3, 6, 11, and 14 weeks after sowing.
[4] Percentage based on estimated number of seedlings (column 5)
[5] The major cause of seedling mortality as determined by isolations:
Siro = Sirococcus strobilinus
Fus = Fusarium avenaceum, F. solani, F. tricinctum
Fus. oxy. = Fusarium oxysporum
Phoma = Phoma spp.
Cyl = Cylindro carpon tenue
Bot = Botrytis cinerea
[6] Number of dead/diseased seedlings in which none of these pathogens were isolated.
[7] Number empty cells at the end of the crop minus dead seedlings removed before count.
[8] Includes diseased seedlings assayed at 3 to 14 weeks plus those counted at the end of the production cycle (about 20 weeks).
[9] Total number of seedlings produced.
[10] Percent of cells sown that produced satisfactory seedlings.

Table 4—Occurrence of selected pathogens on containerized Engelmann spruce seedlings at the USDA Forest Service Nursery, Coeur d'Alene, Idaho - spring 1984.

| | Sirococcus strobilinus | | | | | Fusarium oxysporum | | | | | Cylindrocarpon tenue | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 wks | 6 wks | 11 wks | 14 wks | Total | 3 wks | 6 wks | 11 wks | 14 wks | Total | 3 wks | 6 wks | 11 wks | 14 wks | Total |
| 0281 | 0 | 0 | 0 | 1 | 1 | 9 | 0 | 3 | 3 | 15 | 1 | 1 | 2 | 1 | 5 |
| 0353 | 0 | 1 | 8 | 0 | 9 | 36 | 13 | 9 | 5 | 63 | 5 | 0 | 2 | 0 | 7 |
| 0728 | 0 | 1 | 5 | 0 | 6 | 8 | 6 | 1 | 2 | 17 | 3 | 4 | 2 | 1 | 10 |
| 0747 | 0 | 2 | 45 | 13 | 60 | 90 | 42 | 25 | 13 | 170 | 12 | 15 | 15 | 3 | 45 |
| 0759 | 0 | 4 | 119 | 6 | 129 | 38 | 23 | 17 | 4 | 82 | 5 | 1 | 10 | 0 | 16 |
| 1355 | 0 | 2 | 18 | 2 | 22 | 11 | 2 | 0 | 0 | 13 | 11 | 12 | 9 | 3 | 35 |
| 1670 | 1 | 0 | 4 | 2 | 7 | 23 | 10 | 1 | 0 | 34 | 2 | 12 | 10 | 6 | 30 |
| 4012 | 0 | 2 | 45 | 0 | 47 | 12 | 5 | 2 | 3 | 22 | 8 | 9 | 3 | 3 | 23 |
| 4093 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 4199 | 0 | 0 | 5 | 0 | 5 | 8 | 10 | 3 | 1 | 22 | 1 | 0 | 3 | 0 | 4 |
| 4215 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 |
| 4374 | 0 | 0 | 2 | 0 | 2 | 3 | 1 | 0 | 0 | 4 | 1 | 1 | 2 | 0 | 4 |
| 4793 | 1 | 2 | 14 | 0 | 17 | 6 | 2 | 2 | 0 | 10 | 1 | 0 | 1 | 1 | 3 |
| 4935 | 0 | 21 | 263 | 11 | 295 | 42 | 1 | 3 | 7 | 53 | 6 | 0 | 0 | 0 | 6 |
| 4938 | 1 | 7 | 22 | 0 | 30 | 15 | 0 | 0 | 0 | 15 | 1 | 0 | 0 | 0 | 1 |
| 6053 | 0 | 0 | 18 | 3 | 21 | 13 | 1 | 0 | 2 | 16 | 3 | 1 | 0 | 0 | 5 |
| 6081 | 1 | 5 | 23 | 1 | 30 | 8 | 0 | 2 | 1 | 11 | 0 | 0 | 0 | 0 | 0 |
| 6082 | 0 | 1 | 7 | 0 | 8 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 1 |
| 6086 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Totals | 4 | 48 | 600 | 39 | 691 | 327 | 116 | 70 | 42 | 555 | 61 | 56 | 61 | 18 | 196 |
| Percent | 0.6 | 7.0 | 86.8 | 5.6 | - | 58.9 | 20.9 | 12.6 | 7.6 | - | 31.1 | 28.6 | 31.1 | 9.2 | - |

## DISCUSSION

Diseases of conifer seedlings are common in containerized operations because conditions under which they are grown are often very conducive to pathogen development (James 1984a). Growers usually compensate for expected losses from diseases or other causes by oversowing as much as 20-25 percent of the crop depending on the species and expected losses. Losses from diseases in the 1984 spring crop of Engelmann spruce at the Coeur d'Alene Nursery were less than one percent of the seedlings produced. Losses from empty cells, which may have been due to either germination failures or preemergence disease, were also very low. Therefore, more than enough seedlings were produced to meet or exceed production guidelines. This is the normal situation at the nursery. Engelmann spruce seedling losses were minimal even though no fungicides were routinely applied. Periodic sanitation to remove diseased seedlings as they were discovered helped reduce pathogen inoculum and chances for spread of secondary diseases. Most of the disease found was caused by primary infections, i.e., from seedborne inoculum.

Sirococcus strobilinus caused disease in 18 of 19 spruce seedlots sampled. Occurrence of the disease was random within greenhouses, indicating that the pathogen may be seedborne. Although S. strobilinus was shown to be seedborne on spruce in British Columbia (Sutherland et al. 1981), this has not been demonstrated at the Coeur d'Alene Nursery. Seedlings infected with S. strobilinus were often entirely necrotic, but remained upright, distinguishing them from common damped-off seedlings. Black fruiting bodies of the fungus (pycnidia) were sometimes produced on the surface of cotyledons or young secondary needles of infected seedlings. These became much more prominent when infected seedlings were incubated on media.

Most disease due to S. strobilinus occurred on seedlings 2-3 months old, although some symptoms were found from shortly after seedling emergence throughout the production cycle. If the pathogen was seedborne, a delay in disease expression may occur due to prolonged incubation periods required following infection, host susceptibility related to different stages of seedling growth, and aggressiveness of various isolates. More information is needed on infection and disease development of containerized seedlings including mediating influences of environmental conditions in greenhouses.

On older seedlings (more than 4 months), S. strobilinus often caused a main stem tip dieback resembling the type of disease commonly found in bareroot stock (Schwandt 1981). Tip dieback often led to seedling mortality; however, seedlings that were only partially necrotic were discarded during consolidation.

Sirococcus tip blight occurred at low levels on bareroot ponderosa and lodgepole pine seedlings during 1984 at Coeur d'Alene (James 1985). However, infected beds were some distance from the greenhouses where spruce were grown. Inoculum spread by the fungus is mostly accomplished by water-splash from infected plants (Funk 1972; Nicholls and Robbins 1984). It is therefore highly unlikely that infected bareroot pine was the inoculum source for containerized spruce.

Fusarium oxysporum was most consistently isolated from diseased seedlings shortly after they emerged. This common pathogen is a major cause of damping-off of young seedlings (Graham and Linderman 1983; Landis 1976) and needle tip dieback or mortality of older seedlings (James 1984c; James 1984d) grown in greenhouses. The fungus produced bright orange sporodochia on infected seedlings (near soil line) and on discarded seedcoats.

Other fusaria commonly isolated from diseased Engelmann spruce seedlings included F. avenaceum, F. solani, and F. tricinctum. Fusarium avenaceum occurs worldwide but especially in temperate zones (Gerlach and Nirenberg 1982). The fungus is most often isolated from cereals, but has also been obtained from numerous other plants. It is primarily a saprophyte. However, under conditions unfavorable to its host, the fungus may become aggressive, causing damping-off (Schneider 1958). The role of this fungus as a pathogen of conifer seedlings is unknown. Fusarium solani is a widely distributed species, causing damping-off and root diseases of many different kinds of plants (Gerlach and Nirenberg 1982). This species, often associated with F. oxysporum, causes diseases of seedlings in nurseries (Hodges 1962; Landis 1976). Fusarium solani has been implicated in root rot of bareroot Douglas-fir and Fraser fir (Merrill et al. 1981) and white pine James 1983b). Fusarium tricinctum is commonly isolated from soils and many types of plants (Gerlach and Nirenberg 1982). Although generally considered saprophytic, the fungus has been shown to be pathogenic to some plants (Seemuller 1968). Its role as a pathogen of conifer seedlings is unknown.

Cylindrocarpon tenue is an inhabitant of the roots of many different kinds of plants, especially in tropical areas (Booth 1966). The fungus is also frequently isolated from soils and has been implicated in several root diseases, but not of conifer seedlings (Booth 1966). Therefore, its role as a pathogen of containerized spruce seedlings is unknown.

Other possible pathogenic fungi frequently isolated from diseased spruce seedlings included F. roseum, P. herbarum, P. fimeti, and B. cinerea. Fusarium roseum is a common soil-borne saprophyte (Booth 1971; Gerlach and Nirenberg 1983), although it can be parasitic on conifer seedlings (Morgan 1983). Species of Phoma are common soil-borne fungi frequently isolated from diseased conifer seedlings (James and Hamm 1985). Their role as incitants of seedling diseases is currently unknown and further investigations are needed to evaluate their potential as pathogens. Botrytis is a common pathogen of containerized conifer seedlings including spruce. Disease caused by this fungus usually becomes noticeable late in the crop cycle when seedlings crown canopies become dense (James 1984a). Botrytis was first found colonizing necrotic foliage on spruce seedlings shortly before they were removed from greenhouses and placed outside under shade. However, necrotic foliage could have been the result of hardening seedlings off or infection by S. strobilinus or other fungi.

The medium (Komada 1975) used for isolation of fungi from diseased seedlings proved very satisfactory in suppressing growth of common saprophytic fungi, such as Penicillium and Trichoderma, and bacteria while allowing potential pathogens to grow and sporulate. Growth of Fusarium and Cylindrocarpon was especially enhanced by the medium; Sirococcus and Phoma readily sporulated on the foliage and stems of seedlings incubated on the medium.

This evaluation helps clarify the role of diseases in the production of containerized Engelmann spruce seedlings. Proper greenhouse management techniques such as timely periodic sanitation practices ensured very low disease losses without the necessity of applying fungicides. Most of the pathogens encountered were likely seed-borne, although further tests are required to confirm this. Sirococcus strobilinus was more common on the spruce seedlings than anticipated. The pathogen might be a common colonizer of spruce cones and readily infect seed. Additional work is needed to understand seed infection processes by this fungus.

## ACKNOWLEDGEMENTS

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## APPENDIX

Descriptions of potentially pathogenic fungi commonly isolated from containerized Engelmann spruce seedlings at the USDA Forest Service Nursery, Coeur d'Alene, Idaho:

Sirococcus strobilinus Preuss. (Isolates 84-28, 84-29, 84-30, 84-31)

- -from seedlots 0759, 1355, 0747, 6503 (and all other lots but 4215).
- -colonies very slow growing, reaching 2.0-2.5 cm in diameter in 10 days at 22°C on PDA.
- -colonies convoluted, initially light brown, becoming much darker with age; aerial mycelium sparse, but when present is whitish grey or yellow green in color.
- -sporulation infrequent in some isolates, abundant in other.
- -pycnidia separate or coalesced, exudate rust-brown in color; conidia hyaline, mostly two-celled with pointed ends, and measure 9.5-15.5 x 3-4 μ.

Fusarium oxysporum Schlect. (Isolate 84-33A).

- -from seedlot 4793 (also found in other lots).
- -colonies fast growing, reaching 8.4 cm diameter in 7 days at 22°C on PDA.
- -colonies mostly moist, flesh colored with faint purple pigment embedded within the agar.
- -colonies with isolated fine floccose white hyphae, especially near the center.
- -abundant microconidia produced, borne on short, mostly unbranched phialidic conidiophores, and measure 7-10 x 2.5-3.5 μ.
- -macroconidia fusiform, moderately falcate, pointed at both ends, basal cells pedicellate; mostly 3-5 septate, and measure 30-42 x 3.0-3.5 μ.
- -chlamydospores sparse and mostly intercalary.
- -sporodochia not formed on high nutrient media (PDA) under regular fluorescent light.

Fusarium avenaceum (Fr.) Sacc. (Isolate 84-33B).

- -from seedlot 6082 (also found in other lots).
- -colonies moderately fast growing, reaching 5.3 cm diameter in 7 days at 22°C on PDA.
- -colonies with floccose aerial mycelium, mostly whitish with some rose coloration.
- -colonies produce deep carmine (red-violet) pigmentation, particularly at agar surface.
- -conidia produced on primary conidiophores (arising laterally in the aerial mycelium with little branching), mostly one-celled to 3-septate, and measure 18-22 x 2.5-3.0 μ.
- -conidia produced on secondary conidiophores (densely branched phialides) falcate, widest in the upper third, with distinct pedicellate basal cell, mostly 5 septate; measure 48-60 x 3.0-4.0 μ.
- -no chlamydospores formed.
- -sporodochia formed after 4-6 weeks and appear as yellow-orange slimy growths on sclerotial bodies.

Fusarium tricinctum (Corda) Sacc. (Isolate 84-41)

-from seedlot 0728 (also found in other lots).
-colonies moderately fast growing, reaching 4.5 cm diameter in 7 days at 22°C on PDA.
-colonies with floccose aerial mycelium, growing margin irregularly lobed; portions of aerial mycelium carmine (red-violet), other portions white and ochre.
-colonies produce deep carmine pigmentation, particularly at agar surface.
-microconidia abundant within the aerial mycelium, produced in false heads, mostly one-celled, pyriform to ellipsoid, and measure 8-11 x 4.0-6.5 μ.
-macroconidia only borne on sporodochia which form after 6 weeks (2 weeks under black light) and are orange-flesh colored; macroconidia falcate, slender, widest in the center, tapering evenly to each end, apical and basal cells of equal length, mostly 3-5 septate, and measure 35-48 x 3.5-4.0 μ.
-chlamydospores intercalary, in chains, and hyaline.
-sclerotial bodies ochraceous to cream colored.

Fusarium solani (Mart.) Sacc. (Isolate 84-83).

-from seedlot 0747 (also found in other lots).
-colonies fast growing, reaching 7.0 cm diameter in 7 days at 22°C on PDA.
-colonies moist and zonate, although some sparse, delicate, white aerial hyphae present, especially near colony centers.
-colonies cream-flesh colored and cream pigmentation produced at agar surface.
-microconidia produced within false head in aerial mycelium; microphialides long and slender; microconidia mostly 1-2 celled, oval to ellipsoid, and measure 8-13 x 3.5-4.0 μ.
-macroconidia produced abundantly in cream-colored pionnotes (sporodochia); macroconidiophores short but highly branched; macroconidia thick-walled, slightly curved, with a short, blunt apical and indistinct pedicellate basal cell, 3-5 septate, and measure 30-48 x 4.2-6.0 μ.
-chlamydospores mostly terminal, sometimes in pairs.

Cylindrocarpon tenue Bugn. (Isolates 84-65, 84-66, 84-67, 84-68,84-69).

-from seedlots 0728, 1355, 0759, 0281, and 4012.
-colonies slow growing, reaching 5.6-7.2 cm diameter in 14 days at 22°C on PDA.
-colonies with mostly white felty-floccose aerial mycelium; some isolates with slight yellow and rust-brown aerial hyphae.
-most colonies with cream-colored slimy sporodochia, especially prominent in colony centers.
-pale brown to reddish-brown pigmentation develops on agar surface beneath colonies; intensity of pigmentation increases with colony age and varies among different isolates.
-conidia of one type only (macrocondia); conidia arise from simple lateral phialides or from penicillately branched heads, each branch terminating in one or more simple cylindrical phialide; conidia measure 16-20 x 2-3 μ.
-chlamydospores formed infrequently, globose, solitary or in short chains, terminal or intercalary, hyaline at first and becoming brown with age, and measuring 7-12 μ in diameter.

Phoma herbarum Westd. (Isolate 84-27A).
-from seedlot 0353 (also in several other lots).
-colonies reaching 3.2-4.0 cm in 7 days on oatmeal agar (OA) at 22°C in the dark.
-colonies with sparse aerial mycelium; that produced floccose tufts of charcoal gray (OA) or pink (PDA) irregularly scattered over colonies.
-pycnidial production abundant only on OA, sparse or absent on PDA; pycnidia produce orange exudate.
-reddish-pink pigment commonly produced on agar, most intense at agar surface; pigment turns dark blue to violet upon addition of NaOH.
-conidia ellipsoidal, mostly one-celled and measure 4.5-5 x 2.0-2.5 µ.
-no chlamydospores produced.

Phoma fimeti Brun. (Isolate 84-60B).
-from seedlot 0747 (also in several other lots).
-colonies reaching 2.5-3.0 cm in diameter after 7 days on OA at 22°C in the dark.
-colonies white to olivaceous gray with aerial mycelium moderately dense and not concentrically zoned.
-distinct yellows to saffron pigment produced on OA, becoming more prominent with age; pigmentation does not change with addition of NaOH.
-pycnidia readily produced on OA; sparse or no formation on PDA.
-conidia ellipsoid, mostly one-celled, measure 3-3.5 x 2-2.5 µ, often with one large guttule.
-no chlamydospores formed.

Botrytis cinerea Pers. ex Fr.
-adequate descriptions of this fungus have been given elsewhere and are not included here.